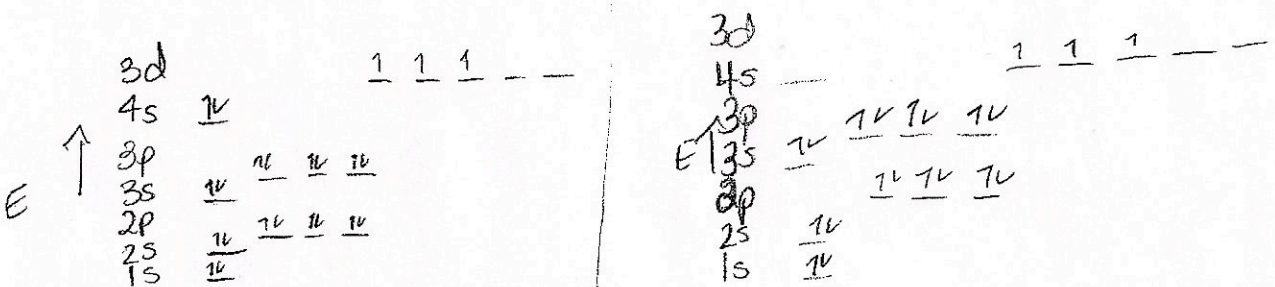
PART B: SHORT ANSWER (60 MARKS) Pay attention to the directions in the questions as some indicate choice. If you attempt more than the required number of questions and do not indicate which ones you would like to have marked, the first two attempted will be chosen.

1a. Write the electron configuration and energy level diagram for vanadium. (label completely)
1b. Write electron configuration for the vanadium 5+ ion
1c. Draw the energy level diagram for the vanadium 2+ ion

/5 a) $V: [Ar]4s^2 3d^3$

b $V^{5+}: [Ar]$

c V^{2+} :



2a. Draw the lewis structure and then identify the VSEPR shape **for 2** of the following compounds. Identify if the structure is polar or non-polar.

i) H_2O -LS

/6 — VSEPR AX_2E_2 bent/V

net dipole ∴ polar

ii) CO_2 -LS

O-C-O — VSEPR linear

←C→ net dipole of zero

∴ nonpolar

iii) PCl_5 -LS

VSEPR trigonal bipyramidal

no net dipole

∴ nonpolar

iv) BI_3 -LS

VSEPR trigonal planar

no net dipole

∴ nonpolar

2b. List the types of intermolecular forces present in i) and ii) . Which one will have the highest boiling point?

H_2O: LDF, dipole-dipole, H bonding

CO_2: LDF

/3 Water has the higher bp because it has more (and stronger) IMFs. More E is req'd to overcome these attractive forces to (l) → (g)

3. Complete 2 of the following 3 types of enthalpy questions.

a. Use Hess's Law to calculate the enthalpy of reaction from the following thermochemical equations:

1. $2C_{(s)} + O_{2(g)} \leftrightarrow 2CO_{(g)}$ $\Delta H = -221.0$ kJ

2. $C_{(s)} + O_{2(g)} \leftrightarrow CO_{2(g)}$ $\Delta H = -393.5$ kJ

3. $2H_{2(g)} + O_{2(g)} \leftrightarrow 2H_2O_{(g)}$ $\Delta H = -483.6$ kJ

for the reaction:

$CO_{(g)} + H_{2(g)} + O_{2(g)} \leftrightarrow CO_{2(g)} + H_2O_{(g)}$

1 flip ÷ 2 $CO \leftrightarrow C + \frac{1}{2}O_2$ + 110.5 KJ

2. same $O_2 + C \leftrightarrow CO_2$ -393.5 KJ

3. ÷ 2 $H_2 + \frac{1}{2}O_2 \leftrightarrow H_2O$ -241.8 KJ

$CO + O_2 + H_2 \rightarrow H_2O + CO_2$ -524.8 KJ

3b. In a calorimeter, a 1.0g sample of magnesium is burned to form MgO. In doing so 100g of water in the calorimeter had a temperature increase of 60°C. What is the molar heat of combustion for magnesium in kJ/mol? (C_{H20}=4.18J/g°C)

$q = mc\Delta T$

$= (100)(4.18)(60)$

$= 25.08$ kJ

$\Delta H = -25.08$ kJ

$Mg = 24.31$ g/mol

$n_{Mg} = \frac{1.0g}{24.31 g/mol}$

$= 4.1 \times 10^{-2}$ mol

$\Delta H = n\Delta H^{\circ}_{comb}$.

-25.08 kJ $= (4.1 \times 10^{-2}$ mol$)\ \Delta H_{comb}$

$\Delta H_{comb} = -610$ kJ/mol

3c. Use the standard enthalpies of formation to calculate the enthalpy of reaction for the following reaction;

$$3\,NO_{2(g)} + H_2O_{(l)} \rightarrow 2HNO_{3(l)} + NO_{(g)}$$

$\Delta H_f\, NO_{2(g)}$ = +33.2kJ/mol, $\Delta H_f\, H_2O_{(l)}$ = -285.65kJ/mol $\Delta H_f\, HNO_{3(l)}$ =-174.1kJ/mol, $\Delta H_f\, NO_{(g)}$=90.2 kJ/mol

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$\Delta H_{reaction} = \Delta H_{prod} - \Delta H_{react}$

$= [(2\,mol \times -174.1\,kJ/mol) + (1\,mol \times 90.2\,kJ/mol)] - [(3\,mol \times 33.2\,kJ/mol) + (1\,mol \times -285.65\,kJ/mol)]$

$= (-348.2\,kJ + 90.2\,kJ) - (99.6\,kJ - 285.65\,kJ)$

$= -258\,kJ - (-186.05\,kJ)$

$= -71.95\,kJ$

4a. For the reaction

$$ClO_{2\,(aq)} + 2OH^-_{(aq)} \rightarrow ClO_3^-{}_{(aq)} + ClO_2^-{}_{(aq)}$$

The rate data in the table below were determined at a constant temperature. Find the rate law equation and the value of k

Initial concentration of reactants and rate of production of products

Trial	Initial $[ClO_2]$ mol/L	Initial $[OH^-]$ mol/L	Initial rate of products mol/(L·s)
1	0.0150	0.0250	1.30×10^{-3}
2	0.0150	0.0500	2.60×10^{-3}
3	0.0450	0.0250	1.30×10^{-3}

14

$r = k[ClO_2]^m[OH^-]^n$

m: $\frac{T1}{T3}$: $\frac{1.30\times10^{-3} = k[0.0150]^m[0.0250]^n}{1.30\times10^{-3} \quad k[0.0450]^m[0.0250]^n}$

$1 = \left(\frac{1}{3}\right)^m \quad m = 0$

n: $\frac{T2}{T1}$: $\frac{2.60\times10^{-3}}{1.30\times10^{-3}} = \frac{k[0.0150]^m[0.050]^n}{k[0.0150]^m[0.025]^n}$ ← could do $\frac{T_1}{T_2}$ and get $\frac{1}{2} = \left(\frac{1}{2}\right)^n$

$2 = 2^n \quad n = 1$

$r = k[ClO_2]^0[OH^-]^n \Rightarrow r = k[OH^-]^n$

using Trial 1 $1.30\times10^{-3}\,\frac{mol}{L\cdot s} = k\left[0.0250\,\frac{mol}{L}\right]^1$

$k = 0.052\ 1/s$

4b. Consider the following;

NO	→	N + O	slow
N + O_3	→	NO_2 + O	fast
O + O	→	O_2	fast

What is the overall reaction that the above reaction was proposed for?

/1 $NO + O_3 \rightarrow NO_2 + O_2$

What is the rate law expression for the reaction?

/1 $r = k[NO]^1$ because use slow step for the rate law.

5. For the following reaction,

$$2NO_{2(g)} + 7H_{2(g)} \leftrightarrow 2NH_{3(g)} + 4H_2O_{(l)} + \text{heat}$$

liquid ∴ not part

a) Write an equilibrium constant expression
b) State **one** method of increasing the concentration of ammonia
c) Explain the effect an increase in pressure would have on the concentration of ammonia

a) $K_{eq} = \frac{[NH_{3(g)}]^2}{[NO_{2(g)}]^2[H_{2(g)}]^7}$

c) ↑P shift to side of lower pressure ∴ would ↑ $[NH_3]$

/3

b) ↑ $[NO_2]$, ↑ $[H_2]$, ↓T, ↑P
remove NH_3 as formed
remove H_2O basically
use Le Chatelers Principle to drive rxn right.

Do Only 2 of the next 3 questions (Questions 6,7 and 8)

6. At a certain fixed temperature, you have the following equilibrium

$$CO_{2(g)} + H_{2(g)} \leftrightarrow CO_{(g)} + H_2O_{(g)}$$

If you originally start with 4 moles of CO_2 and H_2 in a 10L container, find the equilibrium concentrations of all four substances given that the $K_{eq} = 8.3$

$[CO_2] = [H_2] = 0.4 \frac{mol}{L}$

	CO_2	H_2	CO	H_2O
I	0.4	0.4	–	–
C	−x	−x	+x	+x
E	0.4−x	0.4−x	x	x

$K_{eq} = \frac{[CO][H_2O]}{[H_2][CO_2]}$

$8.3 = \frac{(x)(x)}{(0.4-x)(0.4-x)} = \frac{x^2}{(0.4-x)^2}$

/5

E: $0.4 - x = 0.10 \frac{mol}{L} = [CO_2] = [H_2]$

$\sqrt{8.3} = \frac{x}{0.4-x}$

$2.88 = \frac{x}{0.4-x}$

$1.152 - 2.88x = x$

$1.152 = 3.88x$

$x = 0.30 \frac{mol}{L}$

$x = 0.30 \frac{mol}{L} = [H_2O][CO]$

7a. Calculate the molar solubility of magnesium carbonate ($MgCO_3$) if the k_{sp} is 6.2×10^{-8}.

$MgCO_3 \rightleftharpoons Mg^{2+} + CO_3^{2-}$

	Mg^{2+}	CO_3^{2-}
I	0	0
C	+x	+x
E	x	x

$K_{sp} = [Mg^{2+}][CO_3^{2-}]$

$6.2 \times 10^{-8} = (x)(x)$

$x = 2.49 \times 10^{-4}$ mol/L

/4

∴ molar solubility is 2.5×10^{-4} mol/L.

b. If a small amount of 0.6mol/L Na_2CO_3 solution were added to the magnesium carbonate solution what would happen to the molar solubility of magnesium carbonate? What is the term for this?

/1

$MgCO_3 \rightleftharpoons Mg^{2+} + CO_3^{2-}$
0.6 + x

↓ because le chateliers forces equil to shift left to the solid so not as much can dissolve, ↳ common ion effect

8. Calculate the pH of a 0.75mol/L solution of acetic acid ($HC_2H_3O_2$) given that the k_a for the acid is 1.8×10^{-5}

	$HC_2H_3O_2$	$\rightleftharpoons$	H^+	+	$C_2H_3O_2^-$
I	0.75		0		0
C	$-x$		$+x$		$+x$
E	$0.75-x$		x		x

/5

$$K_a = \frac{[H^+][C_2H_3O_2^-]}{[HC_2H_3O_2]} = \frac{(x)(x)}{(0.75-x)}$$

$$1.8\times10^{-5} = \frac{x^2}{0.75-x}$$

assume $0.75-x \simeq 0.75$ as K_a is so small.

$$1.8\times10^{-5} = \frac{x^2}{0.75}$$

$$x^2 = 1.35\times10^{-5}$$

$$x = 3.67\times10^{-3}\ mol/L$$

$$x = [H^+] = 3.7\times10^{-3}$$

$$pH = -\log[H^+] = 2.43$$

9. Are the following salts acidic, neutral or basic? Show your work.

i) NaCl

$Na^+ \rightarrow$ form NaOH (not possible)
$Cl^- \rightarrow$ form HCl (not possible)
∴ neutral

/2

ii) NH_4Br

$NH_4^+ + H_2O \rightleftharpoons NH_3 + H_3O^+$ forms ∴ acidic

$Br^- \rightarrow$ forms HBr (not possible)

Do Only 2 of the next 3 questions (Questions 10,11 and 12)

10. Use half-cell potentials to predict whether the following reactions are spontaneous or not.

a) $Cu^{2+}_{(aq)} + Fe^{2+}_{(aq)} \rightarrow Fe^{3+}_{(aq)} + Cu_{(s)}$

red. OA
oxid. RA
0.77
0.34
RA
OA
∴ not

/2

b) $Ni_{(s)} + Ag^+_{(aq)} \rightarrow Ni^{2+}_{(aq)} + Ag_{(s)}$

red. OA
ox. RA
−0.26
0.80
OA
RA
∴ is

11. Given the following short form cell notation for the **spontaneous** galvanic cell and the following reduction potentials calculate the cell potential.

$E^\circ > 0$

$Sc^{3+} + 3e^- \leftrightarrow Sc_{(s)}$ $E_o = -0.74V$
$Cu^{2+} + 2e^- \leftrightarrow Cu_{(s)}$ $E_o = 0.34V$

RED CAT

$Sc|Sc^{2+}(1mol/L) \parallel Cu^{2+}(1mol/L)|Cu$

ANODE CATHODE

/2

$2Sc_{(s)} + 3Cu^{2+}_{(aq)} \rightarrow 3Cu_{(s)} + 2Sc^{3+}$

$E = E_{cat} - E_{an}$
$= 0.34 - (-0.74)$
$= 1.08V.$

12. Balance the following oxidation-reduction reaction using either the oxidation number method or the half-cell reaction method.

$Ni_{(s)} + MnO_4^{2-}{}_{(aq)} \rightarrow NiO_{(s)} + MnO_{2(s)}$

/2

$H_2O + \overset{0}{Ni} \longrightarrow \overset{2+}{Ni}O + 2e^- + 2H^+$

$4H^+ + 2e^- + \overset{6+}{Mn}O_4^{2-} \longrightarrow \overset{4+}{Mn}O_2 + 2H_2O$

$Ni + 2H^+ + MnO_4^{2-} \rightarrow NiO + MnO_2 + H_2O$

or

ox'd = $2e^- \times 1 = 2$

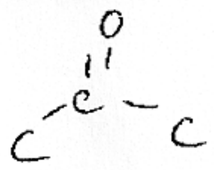
$2H^+ + \overset{0}{Ni} + MnO_4^{2-} \longrightarrow \overset{+2}{Ni}O + MnO_2 + H_2O$

red = $2e \times 1 = 2$

13. Identify the functional group for the following compounds

a) an ether b) a ketone c) an alkene d) an aromatic ring

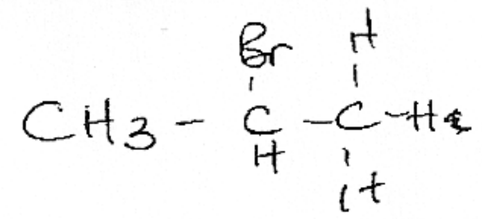
/4

C-O-C  C=C 

14. Draw the products and name them for the following reactions

a)

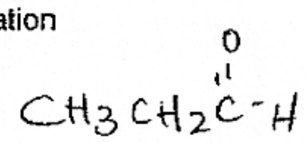
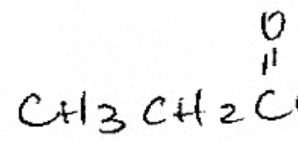
/2

$CH_3-CH=CH_2 + HBr_{(aq)} \rightarrow$ 

2 bromo propane

b)

/4

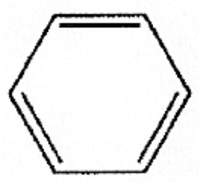
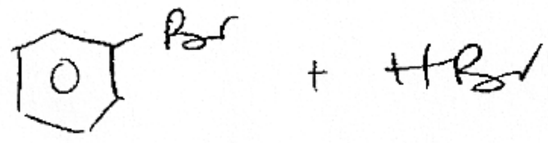
$CH_3-CH_2-CH_2-OH$ —gentle oxidation→  —further oxidation→ 

propanal

propanoic acid

c)

/3

 + $Br_{2(aq)} \rightarrow$ 

THE END!

GOOD LUCK NEXT YEAR